MONITORING OF CORE TEMPERATURE THROUGH THE SKIN: A COMPARISON WITH ESOPHAGEAL AND TYMPANIC TEMPERATURES*

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In recent years the importance of monitoring the temperature of patients during anesthesia and surgical operations has received much attention. In the modern air-conditioned operating room suite the development of hypothermia is fairly common; it is especially important in neonates and older children and in patients who undergo lengthy procedures such as those of neurosurgery and cardiovascular surgery.[1] The rare occurrence of malignant hyperpyrexia is a further justification for the monitoring of temperature in every patient.

The present rectal, esophageal, and tympanic techniques of measuring body temperature, the so-called invasive techniques, cannot be used safely in every patient. Therefore a noninvasive means of measuring body temperature—especially core temperature—was sought.

This new technique depends on creating a zone of zero heat flow across the body shell: this brings the deep body heat to the surface of the skin, where it is measured with a simple electronic thermometer (see Figure 1). The new instrument, called the Deep Body Thermometer (DBT)‡ measures the deep body temperature from the intact surface of the skin by a temperature sensor attached to the patient's skin with double-sided sticky tape. The device is well-suited for use over long periods. The meter is graduated in 0.1°C. divisions from 29 to 42°C. The time required to reach equilibrium is approximately 20 minutes since the automatic switch circuit heats the probe to 37°C. on initial application.

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‡Available from AMI Ambulatory Monitoring, Inc., 731 Saw Mill River Road, Ardsley, N.Y. 10502.

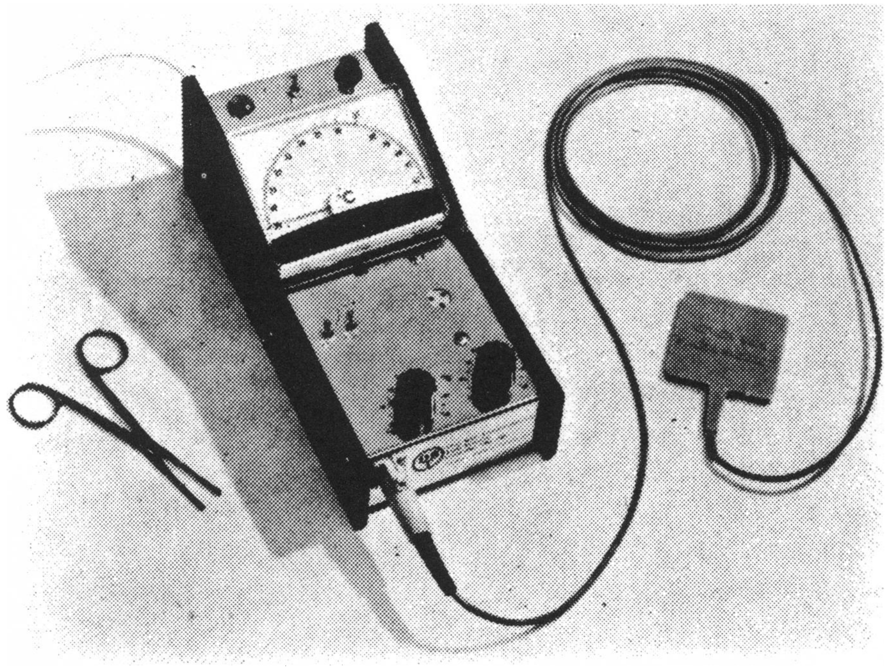

Fig. 1. The control and indicator unit with temperature measuring pad. Reproduced by permission from Dalton, J. C. P.: On taking the temperature. *Lab. Equip. Dig.*, September 1972.

The measurement is made by creating at the surface of the body a region in which no heat flows outward from the core. Since no flow of heat implies no drop in temperature, it follows that the temperature of the surface in this region should be the same as the deep body temperature.

As Figure 2 shows, the temperature-measuring pad is made up of an upper and a lower part. The lower part, a sandwich of two thermistors separated by a layer of thermal insulation, is fixed with one thermistor resting against the subject's skin. These three components form a detector which senses the presence of heat flowing through the thermal resistance by the temperature difference between one side and the other produced by the heat flow. The upper part of the pad is a heater separated from the lower part by a thin layer of insulation. This pad is connected to the control and indicator unit, which contains two amplifiers. The first or comparator amplifier senses the difference between

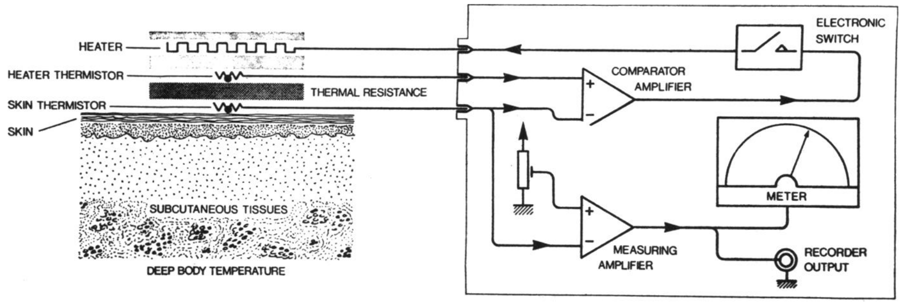

Fig. 2. Schematic diagram of the deep body thermometer. Reproduced by permission from Dalton, J. C. P.: On taking the temperature. *Lab. Equip. Dig.*, September 1972.

the two thermistors and switches the heater on every time the skin thermistor is warmer than the heater thermistor. The measuring or second amplifier takes its signal from the skin thermistor. If there is no flow of heat through the lower layers of the pad, then there can be no flow of heat through the surface layers of tissue into the pad. It follows that there can be no temperature difference between the skin surface under the pad and the deep body temperature. A detailed description has been given by Fox and his co-workers.[2]

In the present study DBT, esophageal temperatures, and tympanic temperatures were compared in 29 patients undergoing various surgical procedures (see the accompanying table and Figure 3).

The DBT pad was placed over the upper sternum. Tympanic temperature was monitored with a disposable thermocouple probe* consisting of copper and constantan thermocouple wires embedded in soft absorbent cotton placed close to the tympanic membrane. Esophageal temperature was monitored by a standard thermistor probe† placed via the nares. Standardization was carried out by means of a bucket of warm water and a mercury thermometer, and the necessary corrections were made.

In this study a close correlation was found among all three measurements: deep body, esophageal, and tympanic temperatures—the only statistically significant difference being between the deep body and esophageal temperatures at one and one and one-half hours following induction of anesthesia.

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*Surg-a-Temp, from Arbrook, Inc., Arlington, Texas.
†Yellow Springs Telethermometer.

SUMMARY OF DATA

Males	11	Types of cases:	
Females	18	Abdominal	11
Total	29	Thoracic	3
Ages: 26 to 80 years		Gynecological	9
		Vascular	3
		Others	3

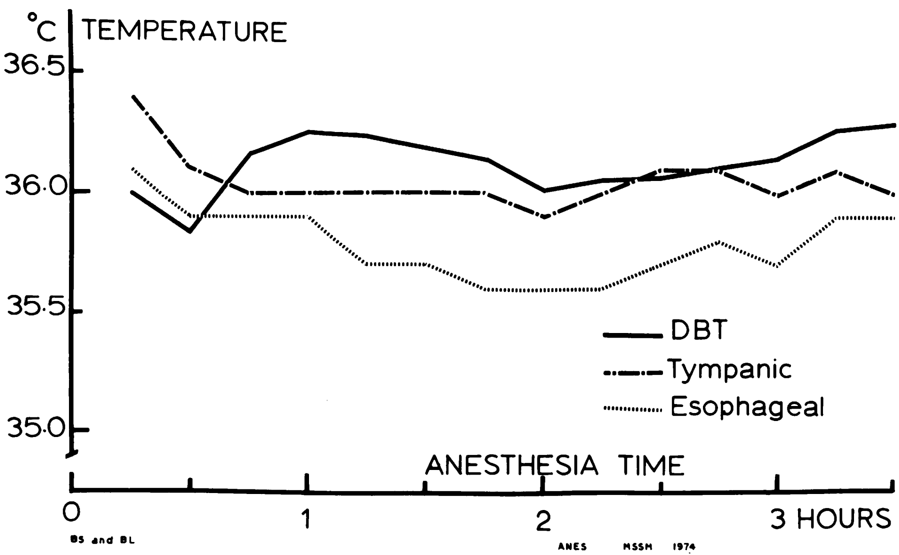

Fig. 3. Comparison of body temperatures in 29 patients.

Figure 3 shows the comparison of average temperatures for each group at 15-minute intervals from 15 minutes after the induction of anesthesia until the end of the operation. In general, there was a drop in temperature after 30 minutes consisting of an average of 0.2 °C. for deep body, 0.2°C. for esophageal, and 0.3°C. for tympanic temperatures. Thereafter there was no significant change in temperature during surgery. Morris[3] reported that the mean body temperatures of patients in an operating room at 18° to 21°C. ambient dropped 1.3°C. the first hour, an additional 0.3°C. the second hour, and 0.1°C. the third hour. In our study we attempted to maintain normo-thermia with a fairly constant room temperature. At the conclusion of anesthesia almost all patients had returned to within 1 °C. of their original temperature. Goldberg[4] reported that the postoperative temperature depression was most marked in elderly patients and that the longer the surgical operation the greater the temperature change. In this study no relation could be demonstrated between decrease in temperature and the age of the patient, body-surface area, or duration of operation.

Esophageal temperature is known to be a good measure of core temperature and specifically of the temperature of the heart.[5] Tympanic membrane temperature has been shown to be a good indicator of cerebral blood temperature.[6] This study shows that a new noninvasive technique (DBT) of monitoring core temperature correlates closely with both the esophageal and tympanic temperatures. The great advantage of the DBT is that one can proceed with monitoring prior to induction of anesthesia since the technique requires only that a pad be attached to the skin. Monitoring can also be carried out for prolonged periods postoperatively for the same reason. The pressure necrosis and discomfort that may accompany the use of an esophageal probe are eliminated, as is the difficulty of placement. The oozing from the ear, especially in heparinized patients, following the insertion of a tympanic probe is also eliminated, as is the possibility of inaccurate measurements caused by the presence of a large amount of cerumen in the ear canal.

The DBT technique is esthetically acceptable to the awake patient and is easily applied. The only disadvantage we found was a technical breakdown of the apparatus twice during the study period; this necessitated repairs at the factory. It is hoped that improvements in the engineering of the apparatus will eliminate this problem in the future.

In conclusion, the DBT technique of monitoring the core temperature compares well with the esophageal and tympanic methods, is noninvasive, and eliminates the hazards and discomforts of the other modes. It is hoped that improved technical excellence of the apparatus will result in a means of simple, safe, long-term temperature monitoring in the operating room, intensive care unit, and neonatal nursery.

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